Layout of An Aggregate Conveyor

at Guy F. Atkinson Company (A)

Mr. Atkins,** a civil engineer at the Guy F. Atkinson Company, was
considering the design of a conveyor for a new concrete plant. The con-
veyor was one of several to be used in a plant which would mix sand, rock,
cement, and water in correct proportions to produce concrete ready for
pouring. Concrete would be taken from the plant by trucks over a two mile
dirt road to the site of the new Delta Pumping Station, part of a major
canal network to distribute irrigation water to Northern California farms.
The Delta Pumping station, started in October 1964, would be completed
in February 1966, after which the concrete plant would be dismantled.

The conveyor was to move rock and sand from ground level to the top
of a storage bin, and would be similar in construction to many which the
company had used before. Mr. Atkins wanted to be sure that the conveyor
was properly adapted to the peculiarities of this situation. Mr. Atkins
commented, "We use a lot of standard equipment in our work but a mark of
a competent engineer is that he can sense small differences in each situa-
tion." He was particularly concerned that a suitable clearance be provided
between the conveyor and its supporting tower. The conveyor rested on the
tower at a skew angle, making it somewhat difficult to determine the clearances.

**Disguised name.

Guy F. Atkinson Company

The Guy F. Atkinson Company is a "heavy construction" contracting organization. Most of its work has been on large projects such as dams, highways, bridges, and harbors, although it contracts smaller jobs as well. Currently its largest project is the construction of two dams and powerhouses in Pakistan for a cost of approximately $354 million. The Delta Pumping Station was, in the opinion of Mr. Atkins, typical of a medium-sized job. Most Atkinson projects have been in the Western United States. Major projects are bid and coordinated from head offices in South San Francisco.

Usually construction projects originate by a customer's invitation to several construction companies for submission of bids. If the Atkinson Company enters bidding competition, a bid is formulated based on the estimated costs of required material, labor, and equipment necessary for the project, as well as management's appraisal of an appropriate profit. Of approximately 500 permanent employees in the Atkinson Company about 20% are engineers, and most cost estimating is done within this group. If a contract is awarded, the company engineers determine a work schedule, often with the aid of mathematical scheduling techniques such as CPM[*]. They also consider the depreciation, maintenance, and income tax implications of any additional equipment which must be purchased or rented for the project, and hire more employees if necessary.

The Delta Project Concrete Mixing Plant

The Delta Pumping Station was to be part of the San Luis Canal system which distributes water to Northern and Central California for use in agricultural irrigation. It would pump water from one canal to another 240 feet higher. The five 66,000 horsepower pumps in the plant would have a total capacity of 2,500 cubic feet per second.

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[*]A construction project using CPM (Critical Path Method) is divided into small components, and the time necessary to complete each component is estimated. After considering the priority of all components, a minimum completion time for the job is determined. Also, those components whose prompt completion is necessary for attaining this minimum are identified.

Determining the Delta Plant Layout

After the Delta Pumping Station job was contracted on August 25, 1964, it was necessary to design a concrete mixing plant which would supply concrete for construction of the pumping station. The plant was to be operative by December 5, 1964, with a mixing capacity of 60 cu.yd./hr. One of the first steps in preparing a specific plant design was to select and arrange the conveyors, bins, and roads so as to achieve low construction and operating costs. As in the design of most plants of this type, an economical layout was not obvious. In general, plant costs are lowered by minimizing the amount of excavation and length of lifting conveyors[*], and by using support towers, conveyors, and other components from previous projects whenever possible.

Factors such as these were considered when initially establishing locations of the aggregate bins and unloading hopper. The arrangement of conveyors and bins shown in Exhibits 1 and 2 appeared to be well-balanced from the point of view of bin accessibility, conveyor length, characteristics of transported material, cost of excavation, etc. This general plant layout was used as a basis for further design of the specific plant components.

Atkinson Company engineers decided that the most economical means of furnishing the large amount of concrete required for the pumping station was to mix it in a specially built plant near the job site. The plant they designed would mix sand; 3", 1 1/2", or 3/4" aggregate[**]; cement; and pozzolan[***] to yield structural concrete. A schematic layout of the mixing plant is given in Exhibit 1. Before dumping material into the unloading hopper the truck driver sets one end of the shuttle conveyor over the aggregate bin which is to receive the material. He does this by selecting the appropriate switch. Then he unloads his truck into the drive-over hopper.

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[*] Conveyor steepness is limited, however, by the tendency of material to roll down the conveyor.

[**] After aggregate is passed through a square mesh screen, its size is said to be equal to the length of sides of the mesh squares.

[***] A fine, silica-like powder used to reduce the amount of cement.

The shuttle conveyor is shown atop the four aggregate bins (after construc-
tion) in Exhibit 2. Each bin has a capacity of 180 tons and stores sand or
one of the three sizes of aggregates. After unloading, conveyor #1 shown in
Exhibit 3, conveys material from the drive-over hopper to the bottom of
the aggregate bin conveyor #2, which elevates it and drops it through a chute
onto the shuttle conveyor #3 which dumps it into an aggregate bin. Either sand
or a blend of aggregates, depending on plant requirements, is drawn from
the aggregate bins by variable speed belt feeders and deposited on a conveyor
(#4) beneath the aggregate bins for transfer to the rescreen plant. This
conveyor moves up to 600 tons per hour of sand or 100 tons per hour of aggre-
gate, the aggregate capacity being limited by the rescreen plant. The
rescreen provides a check on aggregate size and disposes of any undersize
rock. Approximately 90% of all concrete in the pumping station will use
3" aggregate. However, thin walled sections and inaccessible places often
use 1 1/2" or 3/4".

The batch plant, identified in Exhibit 1, has four bins, one for each
aggregate, one for sand, and a two-compartment horizontal silo which
separately stores cement and pozzolan. Sand and aggregate are conveyed
to a weighing hopper, cement and pozzolan are weighed in another hopper,
and ice is conveyed from the ice storage area to an ice-weighing hopper.*
Contents of the weigh hoppers are then discharged onto a conveyor #5 for
transfer to a holding hopper above the mixing plant. Material in the holding
hopper is dumped into a 2 cubic yard rotating drum and mixed with water.
The resulting product is discharged into trucks and transported to the
pumping station for placing.

Designing the Aggregate Bin Feed Conveyor (#2 conveyor)

In choosing the general Delta plant layout, company engineers had
established locations for the unloading hopper and the aggregate bins.
The next major task was to design the aggregate bins and a conveyor (#2)
which would move material from the unloading hopper to the bins. Several
concrete mixing plants had been designed to furnish concrete for past
Atkinson Company projects and were dismantled upon completion of the

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*
 Ice is used to lower the temperature of mixed concrete to minimize
cracking.

projects. Although each mixing plant was different, certain components, such as bins and conveyors, were re-used in several plants. In this way a stockpile of mixing plant components was created and, whenever possible, these components were used instead of newly-purchased equipment. After considering the desired output capacity of the Delta plant and checking the availability of used components, company engineers found that four bins from a previous project would be suitable as aggregate bins in the Delta plant.

In specifying the aggregate bin feed conveyor (#2), the designers were constrained by the locations of the unloading hopper and aggregate bins, i.e. the bottom of the conveyor had to be underneath the unloading hopper conveyor and the top of the conveyor had to be properly positioned above the aggregate bins. From the mixing plant components stockpile Mr. Atkins found a conveyor which he thought was usable as an aggregate bin feed conveyor. Although the conveyor would have to be shortened for the Delta plant, its other specifications, such as belt width, distance between belt support rollers, and belt speed (400 feet per minute), were satisfactory. A portion of this conveyor may be seen in Exhibit 2. Exhibits 4 and 5 give some dimensions of the basic conveyor framework and its position relative to the top belt pulley or head pulley.

Next, the engineers explored means of supporting the conveyor and securing it to the aggregate bins. Several conveyor support towers had previously been designed for other projects and they thought that one of these might be usable with little or no modification for supporting the aggregate bin feed conveyor. This support tower, if used, would be mounted above the aggregate bins as in Exhibit 2. In determining the proper position of the head pulley relative to the support tower, the discharge characteristics of sand and aggregate as well as dimensions of the discharge chute (shown in Exhibit 6) were considered. It was concluded that the head pulley should be located as described by Exhibit 7.

The next factor to determine was the clearance between the conveyor, with its head pulley positioned as shown in Exhibits 4, 5, and 7, and the support tower. The support tower and conveyor are not completely rigid,

and, consequently, the positions of conveyor and support tower after construction may deviate somewhat from the design values. Therefore, the design clearance must be greater than the minimum tolerable clearance. It was felt that a design clearance of 1/2" was necessary to assure absence of contact after construction. If the clearance was at least 1/2", Mr. Atkins would design a means of securing the conveyor to the support tower. Otherwise, he would have to find a way of providing necessary clearance, possibly by modifying the support tower or relocating the conveyor.

He assigned the clearance problem to Mr. Smith[*], another engineer working on the Delta project. Mr. Smith was busy preparing drawings for the Delta plant, but began working on the clearance problem, thinking he would find the answer within about two hours. He first tried to find the clearance using a numerical analysis. The skewed orientation of the conveyor made this difficult, however, and three hours later he had not yet solved for the clearance. He took the problem to Mr. Atkins who then suggested the use of descriptive geometry techniques.

Suggested Assignments

1) If Mr. Smith found the clearance between the conveyor and support tower to be inadequate, what would you suggest that he do?

2) Using the information given in the exhibits, find whether the clearance exceeds 1/2".

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[*]
 Disguised name.

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at Guy F. Atkinson Company (B)

Having found that the conveyor, located as shown in Exhibit 7, would
clear the support tower, Mr. Atkins looked for a means of securing the con-
veyor to the support tower. In the past Mr. Atkins had successfully mounted
aggregate conveyors with pins and brackets as in Exhibit 8, and he chose
to secure the Delta conveyor similarly. Using this method two brackets are
welded to a piece of channel iron which is bolted to the support tower.
These brackets are pinned to similar brackets which are welded to the con-
veyor. The bracketof Exhibit 8 is a type commonly used and was available
from the used equipment stockpile. This bracket is welded to a piece of
angle iron which is bolted onto the conveyor frame. The position of the
brackets and angle iron along the length of the conveyor is chosen to align
the pin holes. The size of these brackets is such that the perpendicular
distance between the bottom of the conveyor frame and the center of the pin
holes is 6".

Beneath the steel plate floor of Exhibit 8 are the steel members which
appear in Exhibits 7 and 9. Since L of Exhibit 9 was stronger than members
M or D, Mr. Atkins wanted one end of channel E to be bolted to L and the
other end bolted to channel F, which would be welded between members L and M.
The position of members E and F and height of the support tower brackets
would be varied to permit pinning of the conveyor and support tower brackets.
Mr. Atkins also used descriptive geometry to attack this new problem.

Suggested Assignments

1) If you were Mr. Atkins, how would you determine the bracket locations?

2) Using descriptive geometry, find the locations of both sets of brackets.
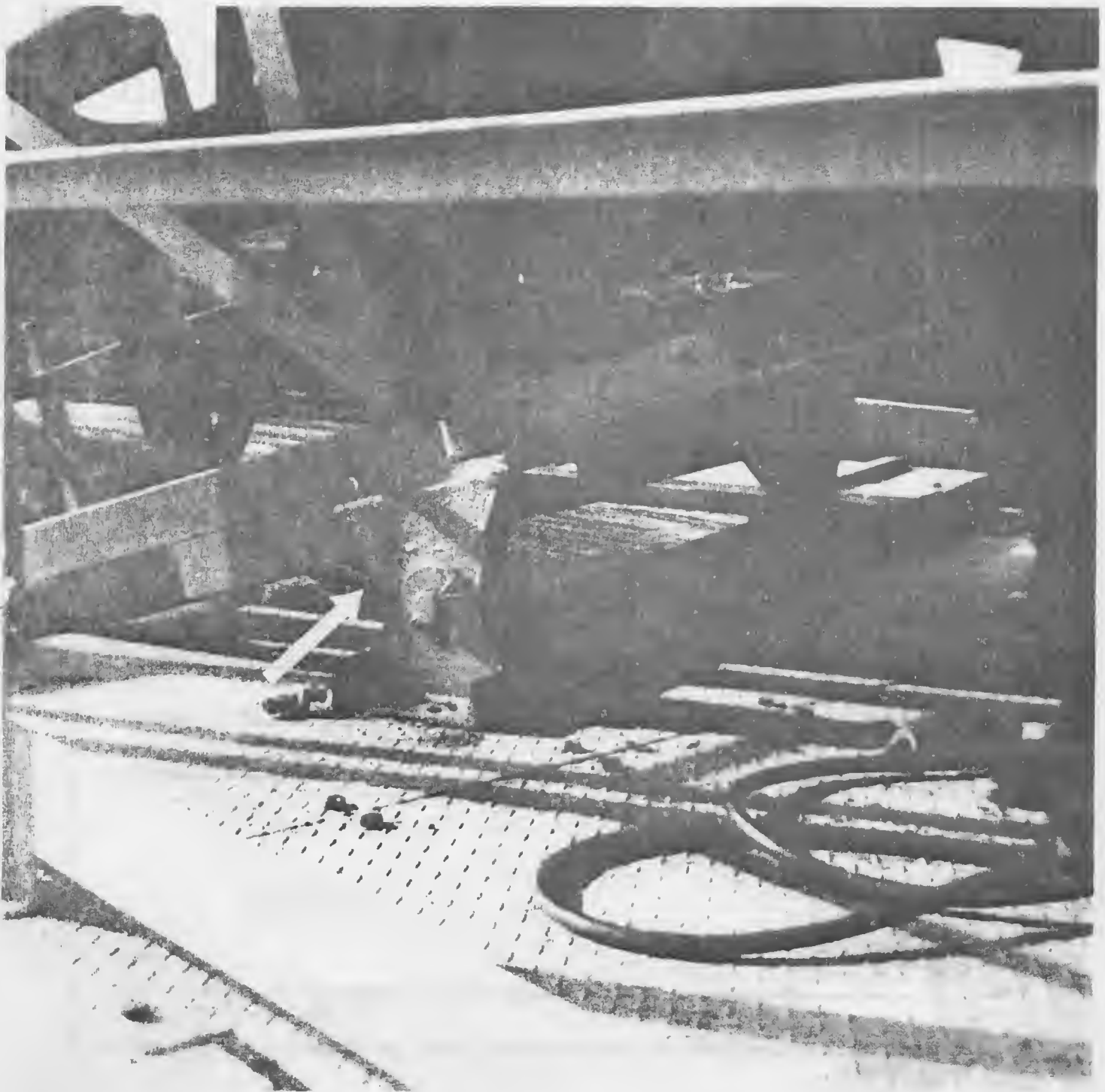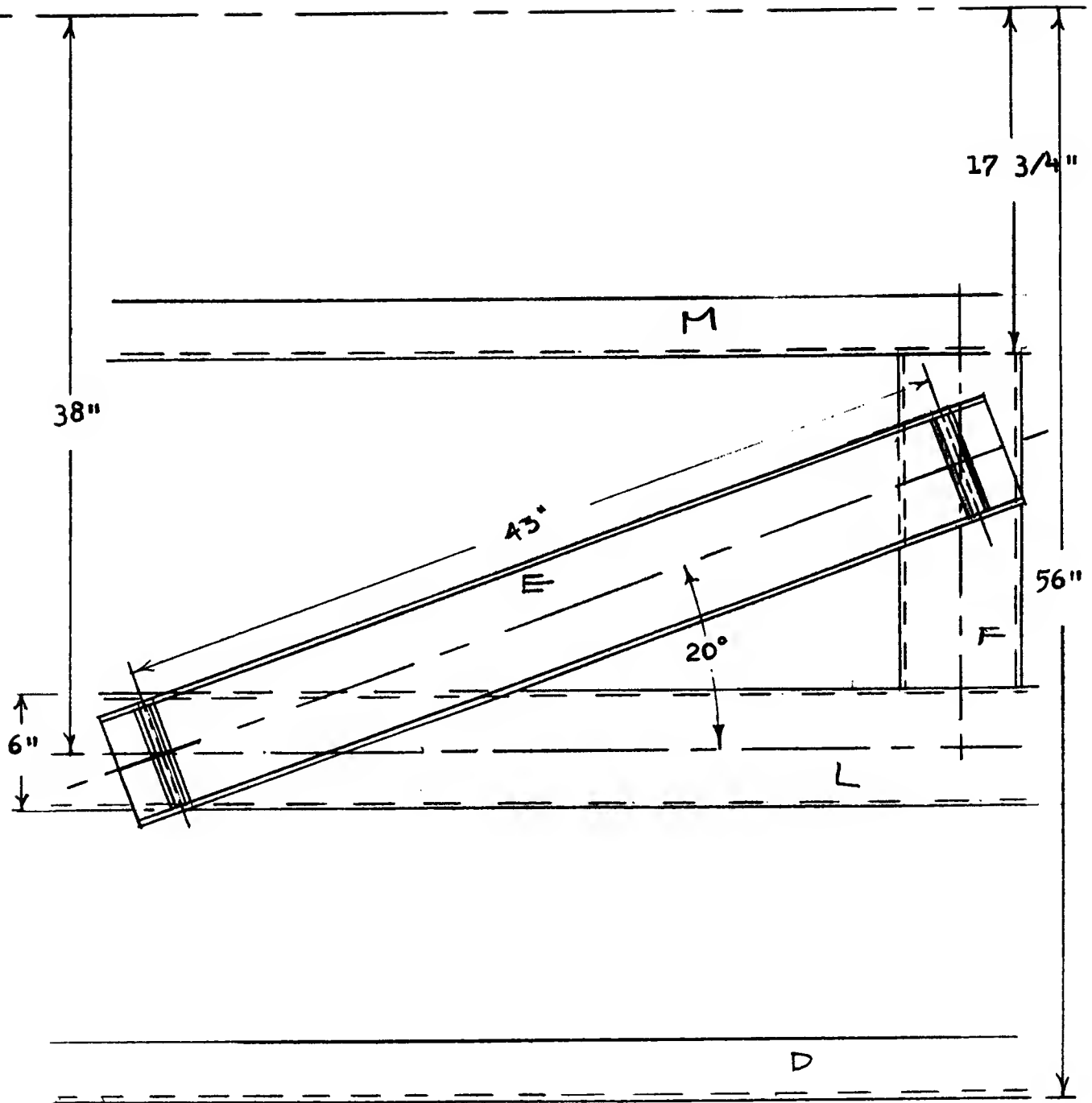
Figure 8   Conveyor Mounting Brackets

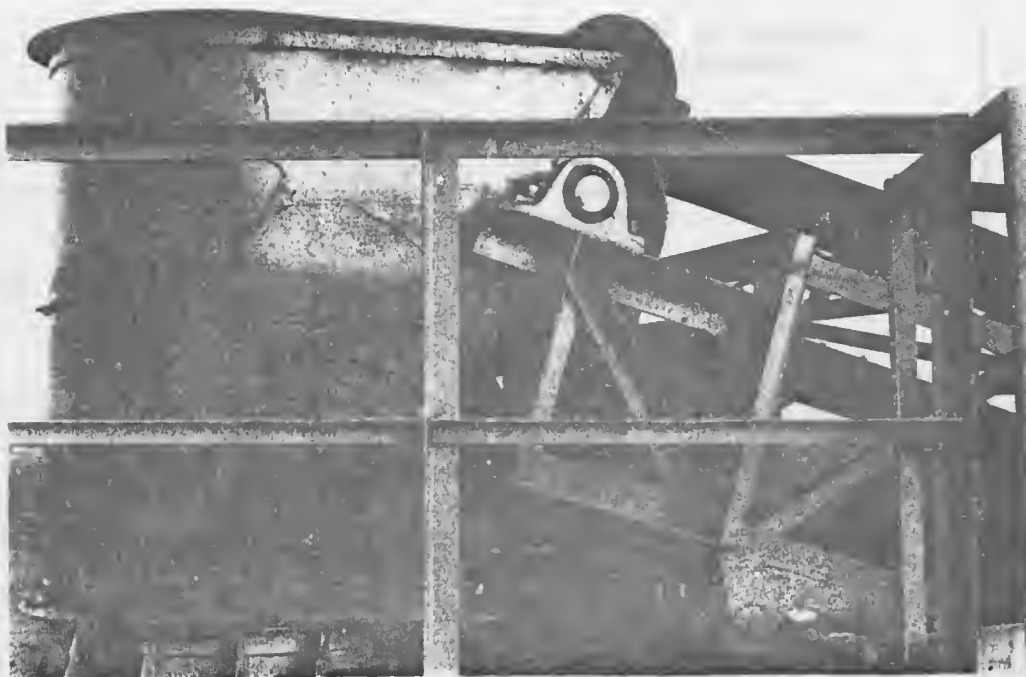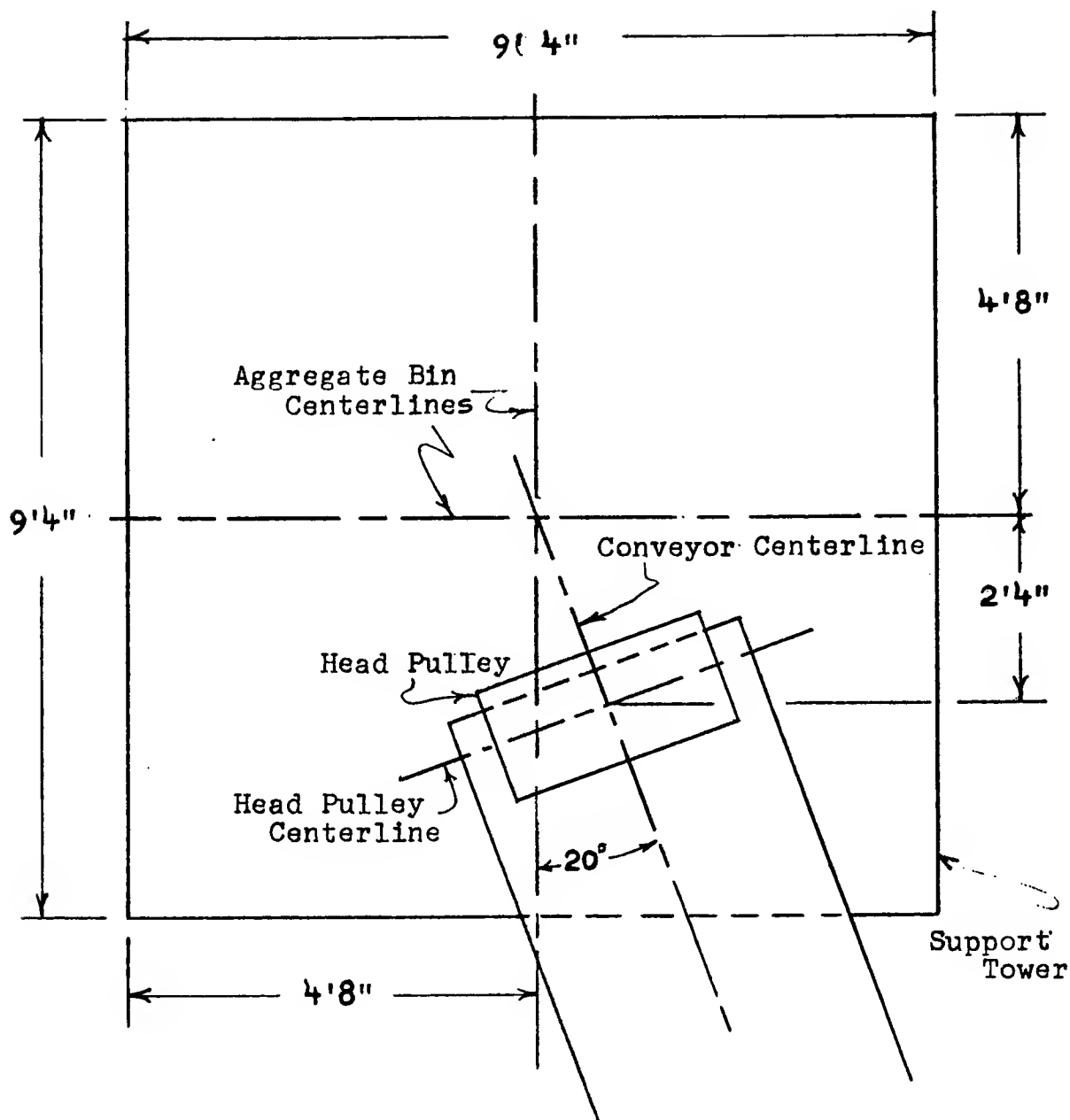Figure 9 - Plan View of Support Tower Members

Figure 6   Discharge Chute

(Conveyor #2)

9' 4"

4'8"

9'4"

Aggregate Bin
Centerlines

2'4"

Conveyor Centerline

Head Pulley

Head Pulley
Centerline

20°

Support
Tower

4'8"

The top of all support tower
members shown are in the same
plane.

Centerline of head pulley is
3' 6" above support tower
platform.

Figure 7 - Schematic Plan View of Support Tower
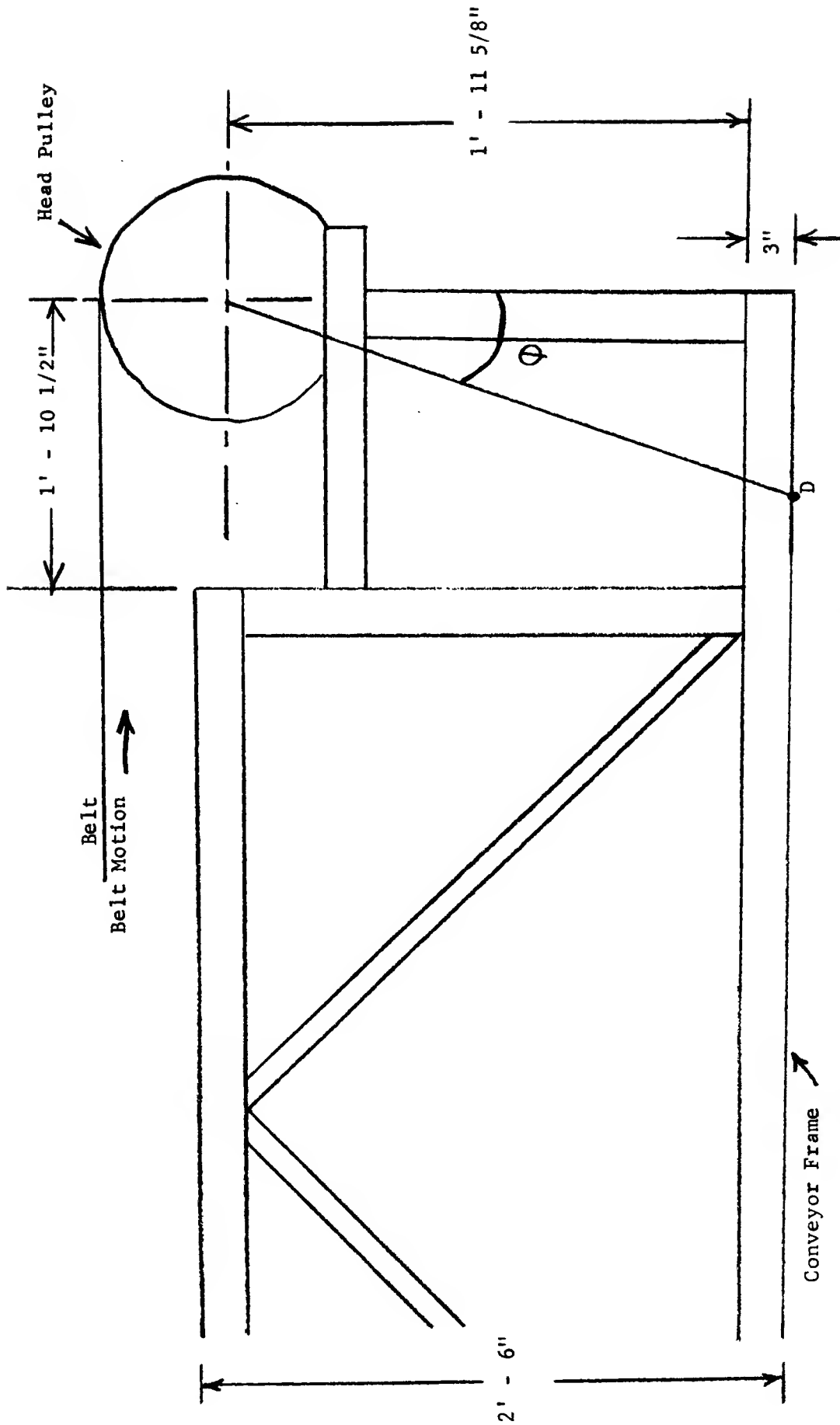
Distance between centerlines of head and tail pulley = 96' - 6"

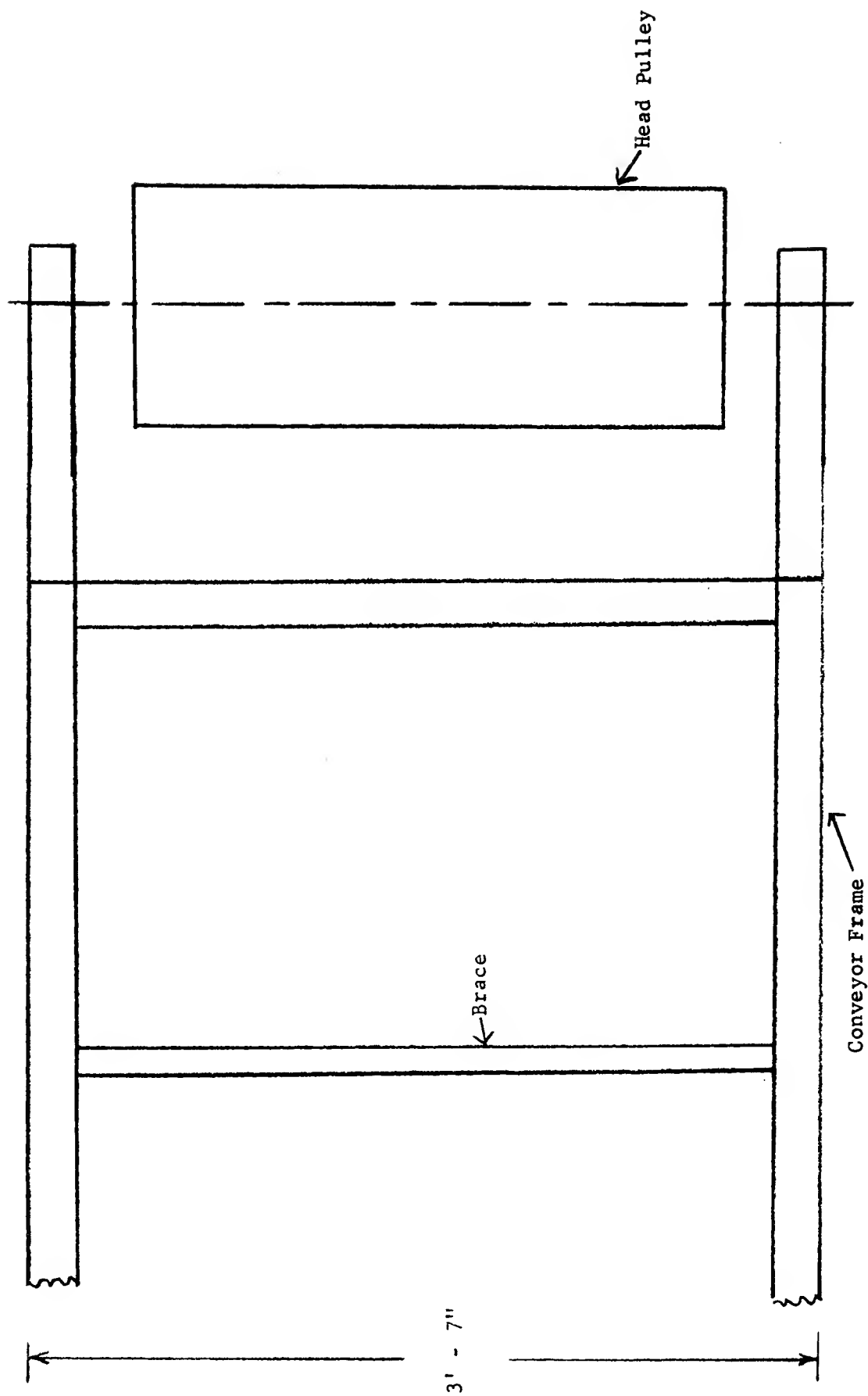Figure 4 Schematic Profile of Conveyor Frame and Head Pulley
(Conveyor #2)

Head Pulley

Brace

Conveyor Frame

3' - 7"

Figure 5 Schematic Plan View of Conveyor Frame and Head Pulley
(Conveyor #2)

Figure 1 Delta Plant Layout

Mixing Plant

Ice Storage Area

Batch Plant &
Weighing Hopper

Storage Silos

El. 171'

Conveyor (#5)

Ice Weighing
Hopper

El. 140'

El. 176'

Rescreen

Cement and Pozzolan

Aggregate Bins

Tower

Shuttle Conveyor (#3)

El. 181'

Conveyor (#2)
(Aggregate Bin Feed)

Conveyor (#1)

Truck Unloading Hopper

El. 150'

El. 143'

Conveyor (#4)

Elevations refer to centerlines of conveyor pulleys.
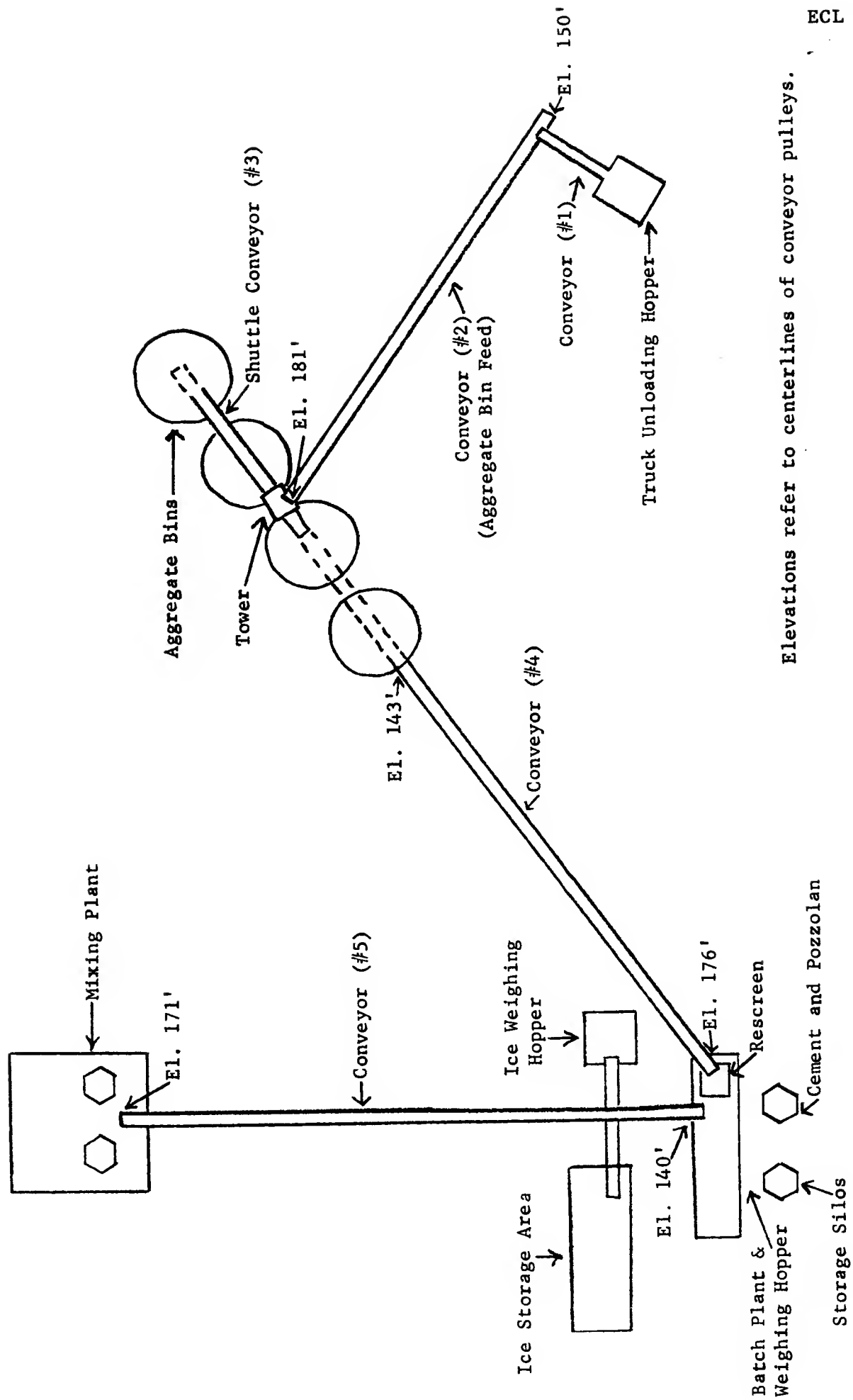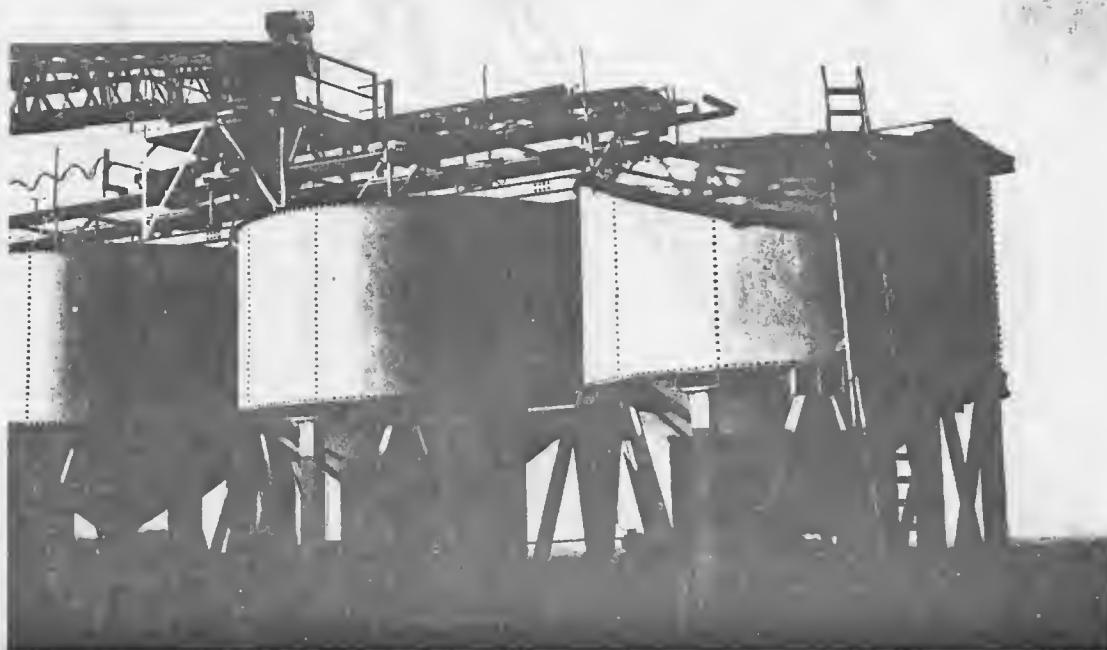
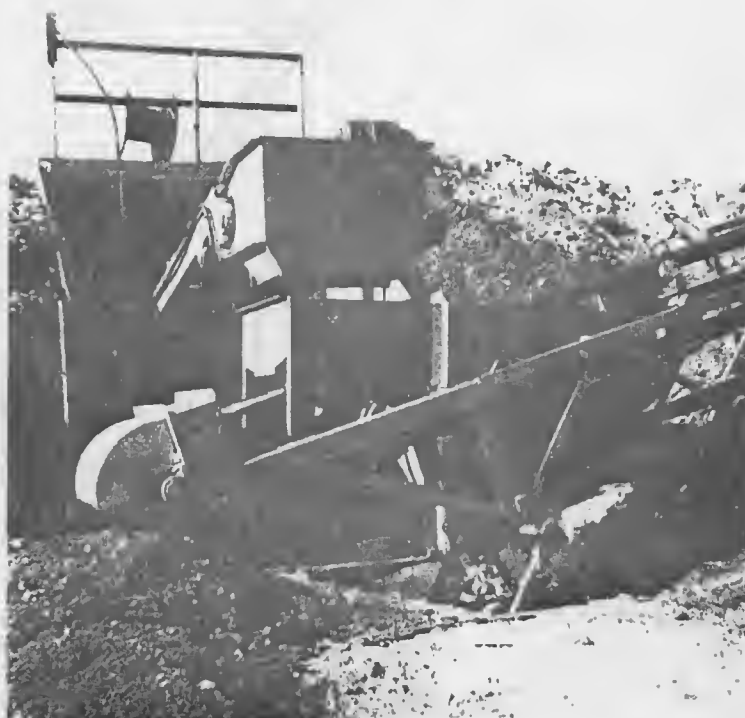Figure 2 Aggregate Bins and Conveyors
(Conveyors #2 and #3)

Figure 3 Unloading Hopper Conveyor
(Conveyors #1 and #2)

Instructor's Note

This case shows a simple design and geometry problem in the context of a company who modify existing equipment to suit new jobs. This type of situation is very common in industry. It is far less romantic than the design of brand new, far-out devices, but equally important and equally demanding of engineering skill.

Suggested Solutions:

Figure 10 shows solutions to the conveyor clearance and bracket loca-tion problems. The first task faced by Mr. Atkins was basically that of finding the distance between two skew lines. One of these, lines, of course, is that top edge of the support tower which is beneath the conveyor. The other must be line AB, since the pulley centerline is parallel to the support tower top plane, and AB is longer than CD (both must have the same slope). Suggested steps in solution follow:

A. Distance between AB (on conveyor bottom) and support tower.

1) Construct enlarged top view of support tower corner, showing conveyor.

2) Draw H-1 fold line parallel to conveyor sides. View of conveyor side will then be "true" - showing true angle of rise for conveyor.

3) Locate a side view of the support tower in the new view.

4) Locate in the side view, point K (pulley centerline) 3' 7" above support tower top plane.

5) Using information given in Figures 1 and 4, construct through K a line having the true angle of rise (rise of 31' over a conveyor length of 96.5').

6) Using information given in Figure 4, locate plane of conveyor

frame bottom (pulley centerline to CF bottom = 2' 2 5/8"). Label
points A and B (A below K).

7) Construct view P to obtain an end view of the support tower
top edge. When line AB extended is projected into this new view,
the clearance can be measured directly (about 2"0.) Actually, it
can be seen from view 1 that clearance is adequate.

B. Bracket location. (Only views H and 1 are used for this solution.)

1) Draw members L and M from Figure 9 in view H of part A solution.

2) Locate line GH, for centers of support tower brackets, where
vertical projector from the conveyor frame edge intersects the center-
line of member L.

3) Project GH into the side view (result is a point).

4) In the side view, draw a locating line 6" below the conveyor
frame. Where this line crosses the GH projector locates the support
pin (point R).

5) Construct RP perpendicular to the conveyor frame (AB);
location of the conveyor brackets is now determined, and the brackets
may be located in the top view H.

Discussion Questions:
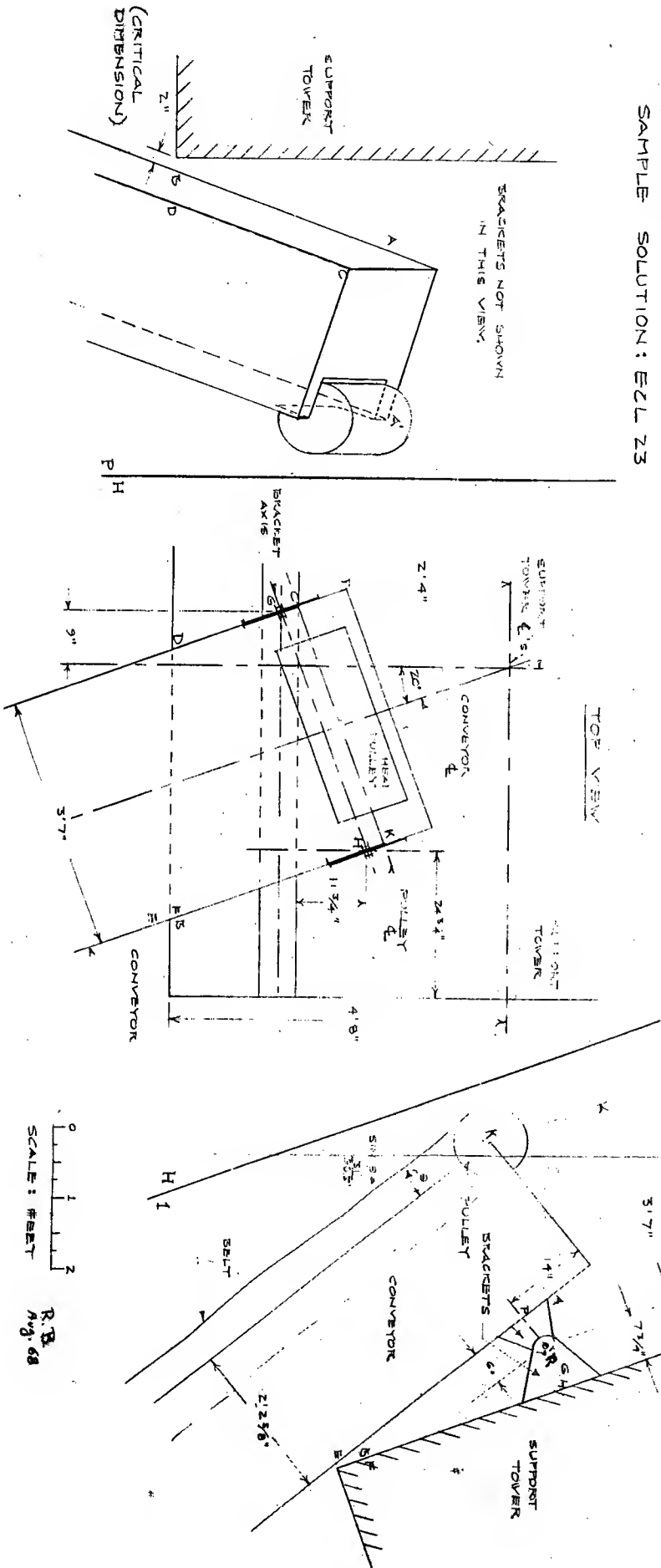
Page 6 Number 1.

If Mr. Smith's descriptive geometry solution showed insufficient
clearance, Mr. Atkins would need to modify the installation to provide
clearance. This could, of course, be done in many ways; the position of
the support tower top edge could be changed, the conveyor frame could be
altered, or the means of support could be changed. The best course, however,
would certainly be simply to raise the upper end of the conveyor by an

amount adequate to provide the required clearance. It is unlikely that
an increase in height of several inches over a length of 96 feet would
cause material to roll back down the belt.

Page 7   Number 1.

   Clearly the bracket locations may be found using descriptive geometry
as in the solution shown on Figure 10. Some students may suggest, however,
that in actual practice the conveyor would simply be jacked into position
and the brackets then fit and welded on the spot. They would probably be
right; such a solution would save engineering time and reduce the chance
of error.

FIGURE 10

SAMPLE SOLUTION: EZL 23

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